MINING, MILLING, AND MANUFACTURING METHODS AT THE BLUE DIAMOND CORP.'S GYPSUM PROPERTY, CLARK COUNTY, NEV.

BY GEORGE H. HOLMES, JR.

* * * * * * * * * **Information Circular 7555**

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INTRODUCTION AND SUMMARY

This paper, which describes mining methods and milling and manufacturing operations at the gypsum property of the Blue Diamond Corp., is one of a series on mining methods and practices being prepared by the Mining Division of the Bureau of Mines.

The property comprises about 4,000 acres and is in secs. 30, 31, 32, and 33, T. 21 S., R. 59 E., and secs. 5, 6, 7, 8, and 9, T. 22 S., R. 59 E., M. D. B. and M., Clark County, Nev., approximately 23 miles by paved highway southwest of Las Vegas, Nev. (fig. 1).

This circular summarizes the history of company operations, describes physical features, labor and living conditions, and the geology. The method of exploration is outlined, and the section on mining methods contains descriptions of open-pit and underground systems, including loading and transportation methods.

The crushing plant and tramway are described, as well as plaster-mill and board-plant practices. The boiler plant and organization are described, and wage scales are contained in the concluding section of the circular.

ACKNOWLEDGMENTS

Acknowledgment is made to the Blue Diamond Corp., 1650 South Alameda Street, Los Angeles, Calif., for permission to publish this paper and to the company's staff at Blue Diamond, Nev., for their valuable assistance and cooperation.

Special acknowledgment is due H. L. Waldthausen, Jr., works manager, who supplied data on mining methods, furnished photographs and drawings, and greatly assisted in preparing this manuscript; to the Rogers Iron Works Co., Joplin, Mo., for drawings of the portable scraper loader, and to the Joy Manufacturing Co., Pittsburgh, Pa., for drawings and information on the rock loader and shuttle car.

Free use has been made of Bureau of Mines Information Circulars[2] for history and early operations.

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[2] Bradley, W. G., Methods and Costs of Mining and Crushing Gypsum at the Mine of the Blue Diamond Corp. (Ltd.), Arden, Nev.: Bureau of Mines Inf. Circ. 6615, September 1932.
Vanderburg, William O., Reconnaissance of Mining Districts in Clark County, Nev.: Bureau of Mines Inf. Circ. 6964, November 1937.

HISTORY

The occurrence of gypsum in the Spring Mountains was known as early as 1909. Gypsum was mined from a deposit about 5 miles west of Arden by the Arden Plaster Co. and the U. S. Gypsum Co. from 1909 to 1931, when operations were terminated because the deposit was exhausted.

The Blue Diamond Corp. investigated an extensive gypsum property 13 miles west of Arden in 1923 and started actual development work in 1925. An 11-mile railroad spur was built between the property and the main line of the Union Pacific Railroad at Arden, and an aerial tramway was installed to transport ore from the deposits to the railway loading bins.

A camp was built and a crushing plant was constructed adjacent to the tramway loading terminal. Power was supplied by Diesel generators. Gypsum was mined, crushed, screened, and shipped to the company's plaster mill in Los Angeles for processing and to various cement plants.

During 1941 the plaster mill was moved from Los Angeles to its present site at Blue Diamond, and a board plant was constructed. Transmission-line power was brought in, and in 1942 construction was started on houses at the company village.

Plant capacity was expanded in 1946 with the installation of an additional roller mill and calcining kettle. Output from the board plant was doubled; the tramway was revamped with a resultant increase in capacity; and the boiler plant was augmented by an additional boiler. Twelve new houses were built in the village, and a new pumping system was installed.

Steel ore bins and a new tramway loading terminal were constructed during 1948.

The high quality and consistent uniformity of grades of the various plaster and plaster-board products has created a wide demand for molding and building use. These products, together with shipments of raw gypsum to the Portland cement industries and ground raw gypsum to fertilizer users, has reflected in the company's steady rate of production.

Present rate of mine production is 900 tons daily, of which 150 tons of screened raw gypsum is shipped to the Portland cement plants, and 750 tons are calcined. Finished plasters and the board mill consume 300 and 290 tons of calcined gypsum daily.

PHYSICAL FEATURES, COMMUNICATIONS, AND UTILITIES

The gypsum deposits are on the tops of a series of steeply rising hills that lie along the foothills of the Spring Mountain Range in southeastern Nevada. Altitudes range from 4,300 to 4,750 feet. The plant and village are situated along the base of those hills at an altitude of about 3,400 feet. A 5-mile graded dirt road connects the plant and the mine workings.

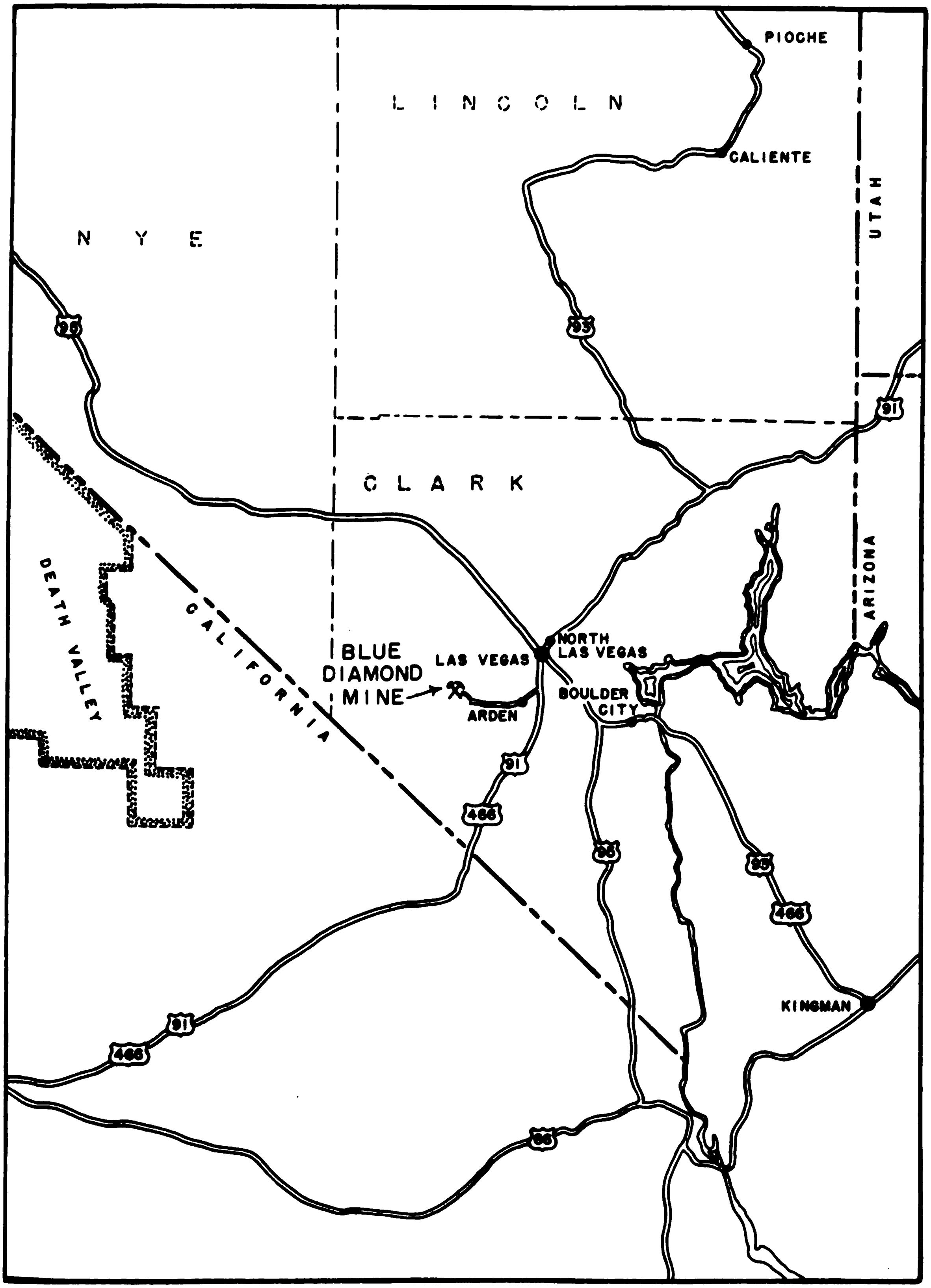

Figure 1. - Location map, Blue Diamond mine, Clark County, Nev.

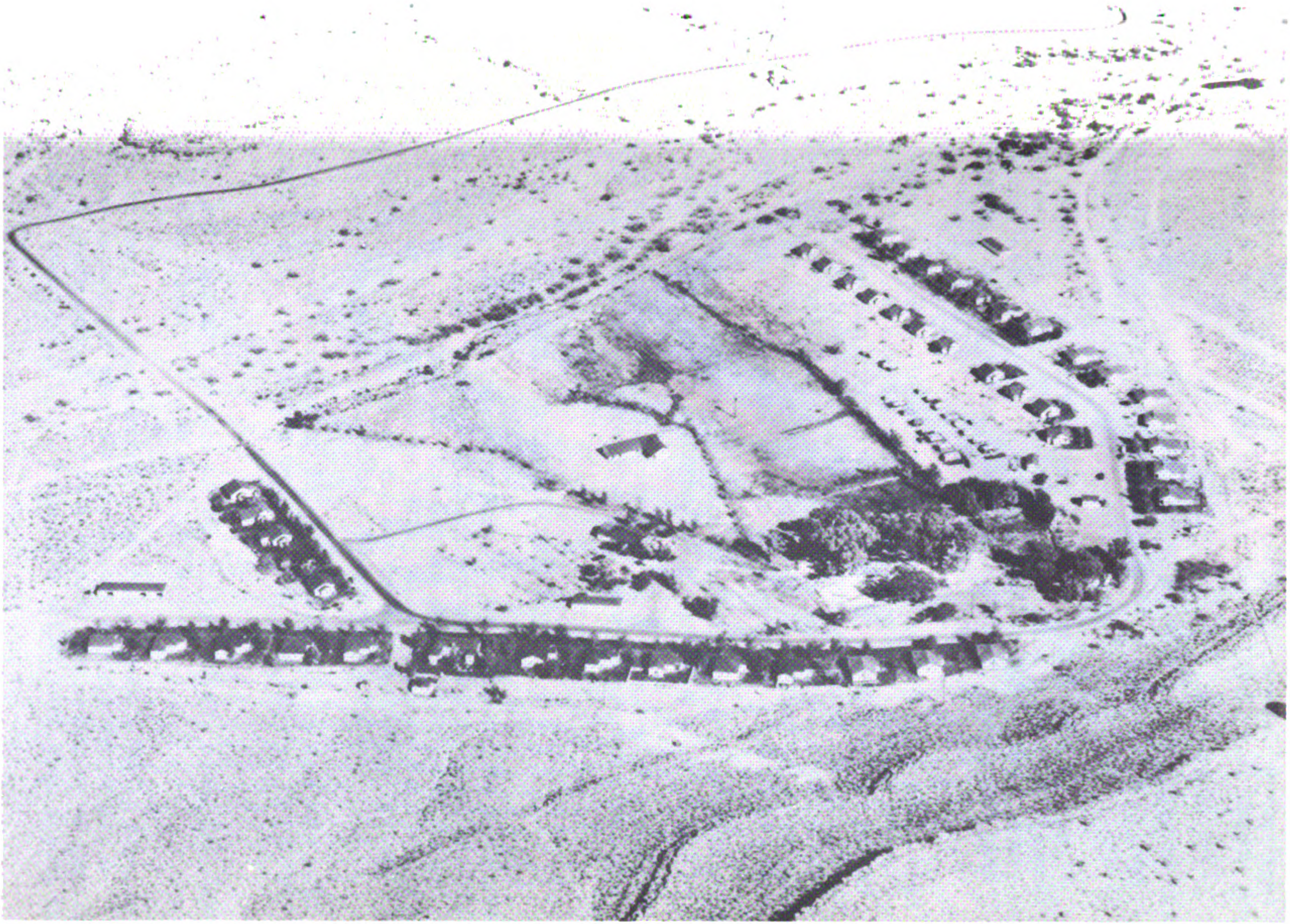

Figure 2. - Village of Blue Diamond.

A semi-arid climate prevails in this area, with hot, dry summers and moderate winters. Operations have not been seriously impeded by the light snow falls, although a severe winter, such as that of 1948, will hamper production.

A paved road connects the plant with U. S. Highway 91, 15 miles to the east. An 11-mile spur extends from the property to the main line of the Union Pacific Railroad at Arden.

Hoover Dam power is transmitted over a 34,500-volt branch of the Southern Nevada Power Co.'s Las Vegas-Goodsprings line. Outside telephone connections are available at the main office, and a company-owned intercommunication system connects the office with the plant, shops, and mine office.

Water is obtained from a 60-foot well sunk in a dry wash about a mile southwest of the plant. An electrically driven deep-well pump delivers 362 g.p.m. to a 20,000-gallon storage tank, from which it is delivered by centrifugal pumps through a 4-inch pipeline to storage tanks serving the mill and boiler plant and the village. A new concrete pump house constructed adjacent to the well houses two series-connected, 20-horsepower, electrically driven centrifugal pumps in parallel with a 25-horsepower centrifugal pump.

Purity of the water is assured by automatic chlorination before it enters the pipelines. Daily consumption averages 160,000 gallons.

A motor-driven, high-head, duplex piston pump working under pressures of 400 to 500 p.s.i. pumps water at a 50-g.p.m. rate to the mine and upper camp.

LABOR AND LIVING CONDITIONS

Mining, hauling, and crushing operations are on a one-shift, 6-day week basis, with the exception of a wagon-drill crew that operates on night shift. An average of 38 men are required for this work. Mill, board, and boiler plants are on a 24-hour day, 6-day week basis, which requires about 117 men. Six hourly-pay workers are employed at the cookhouse, warehouse, and office. Staggering of work shifts puts workers on a 40-hour-week basis.

The supervisory force consists of 18 employees - one at the mine, six at the mill and board plant, nine office men, and one each for the store and for maintenance.

Hourly-wage employees are members of the United Cement, Lime, and Gypsum Workers, which is affiliated with the A. F. of L.

The company village at Blue Diamond comprises 46 modern one-, two-, and three-bedroom frame houses for married supervisory and key employees, a trailer camp, and a grade school that has a current attendance of 40 pupils (fig. 2). A company-owned school bus transports children of high-school age to and from Las Vegas.

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A camp for 50 men, situated just south of the board plant, consists of bunkhouses, bathhouses, and a commissary and cookhouse.

A second camp was formerly maintained at the mine for mine workers, but for economic reasons it has been combined with the plant camp, and employees are transported to and from mine workings in company vehicles. Several modern residences also are maintained by the company close to present mine workings.

As accommodations are not available for all employees, it is necessary for some to live in Las Vegas and neighboring towns.

GEOLOGY

The gypsum deposits occur in gently westward-dipping sedimentaries near the top of a series of fault escarpments. Block faulting has further disturbed the formations (fig. 3).

Stratigraphically, the sedimentary series comprises a limestone capping underlain by a narrow shale and clay stratum. The No. 1 gypsum bed underlies these shales and clays, but its narrow thickness, ranging from 4 to 8 feet, makes it uneconomical for mining. A comparatively thick stratum of gypsiferous shale and clay forms the footwall of the No. 1 bed and the roof or hanging wall of the No. 2 gypsum bed, which is also too thin for economical mining.

Underlying the No. 2 bed is a layer of mixed shale and gypsum and gypseous clay followed by the No. 3 gypsum bed. This bed contains gypsum of high quality, ranges in thickness from 12 to 20 feet, and has been one of the principal producing beds. Entries have been driven on this bed for varying distances, with the gypsum becoming more or less anhydrous in areas where the overlying strata exceed 100 feet. Material removed during stripping operations requisite to preparing the No. 3 deposit for underground mining comprises part of the No. 2 bed and underlying strata and has been found suitable for use as "stucco"-grade gypsum.

A limestone member ranging up to 30 feet in depth but averaging 16 to 22 feet underlies the No. 3 bedded deposit and forms the hanging wall of the No. 4 gypsum bed. This lower deposit ranges in thickness from 12 to 18 feet and is in turn underlain by limestone. The Nos. 3 and 4 gypsum beds are the principal producing deposits.

Faulting and gentle folding have tilted the formations, but the general trend is north-south with moderate dips to the west. Certain blocks in the area have been greatly eroded; in some instances, the strata, overlying the limestones above the No. 4 gypsum bed have been removed completely. The No. 10 area, currently being mined by quarrying, is an example of this erosion.

Dirt-filled solution cavities in sedimentary strata occasionally extend through underlying gypsum beds, diluting the ore with waste and forcing abandonment of mining in the immediate area.

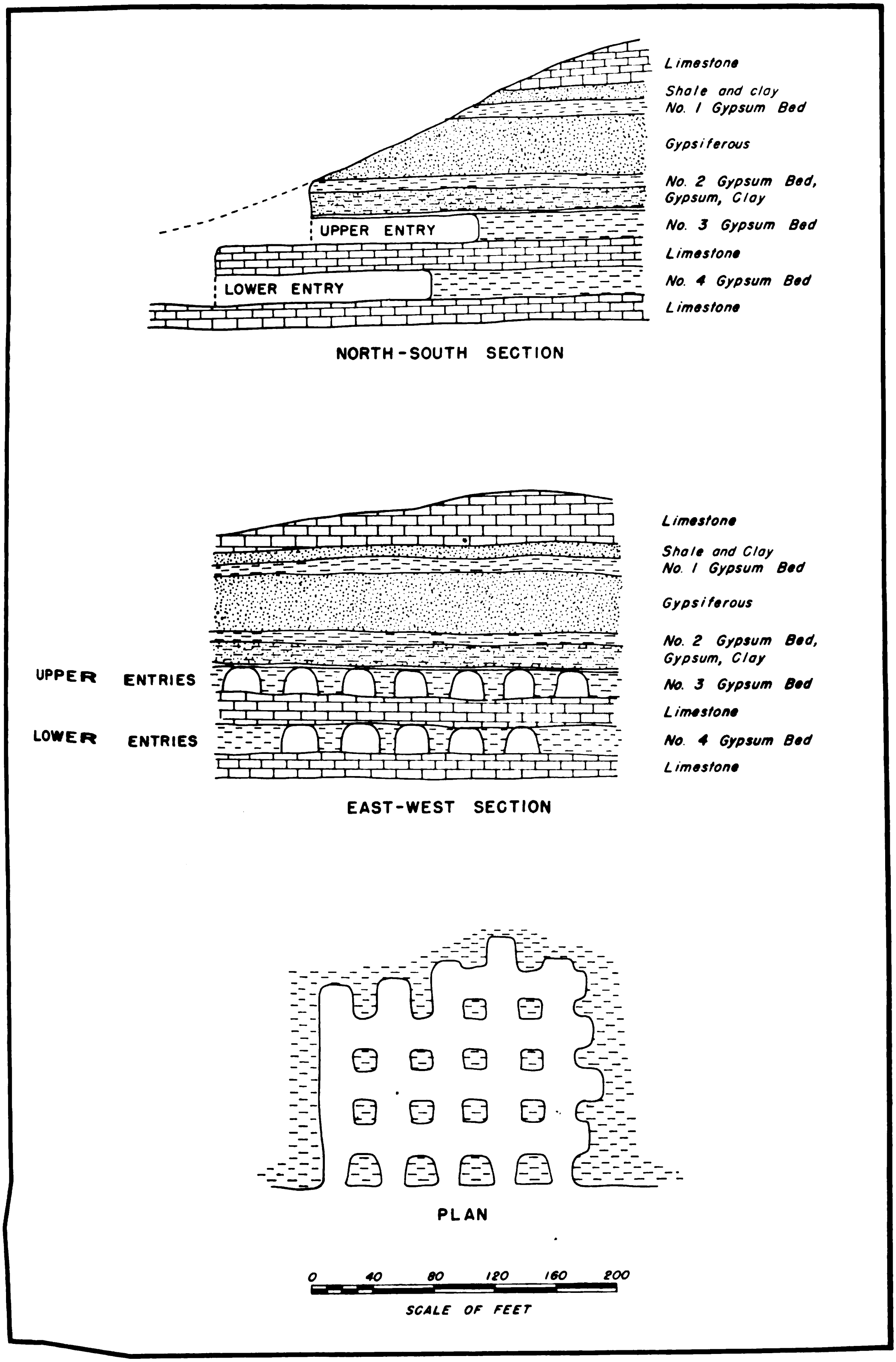

Figure 3. - Typical plan and sections showing workings and geology.

THE ORE

The rock gypsum from the No. 3 and 4 deposits is generally white in color, opaque, and granular massive. Selenite, a colorless to dark-brown crystalline variety of gypsum and showing a distinct platy cleavage, is found occasionally.

Gypsum has a hardness of about 2.0, and a factor of 140 pounds per cubic foot in place is used in tonnage estimates. An average analysis of the ore is:

	Percent
$CaSO_4$	78.43
SiO_2	.65
$MgCO_3$	.25
Al_2O_3, Fe_2O_3	.02
H_2O	20.65

The "stucco"-grade gypsum is reddish in color, contains a mixture of gypsum, clay, and sandstone, and is considerably lower in grade.

Anhydrite is similar to gypsum but contains no water of crystallization. It is grayish in color, granular massive, and has a hardness of about 3.5. Its characteristics make it unsuitable for use in gypsum products.

EXPLORATION

The gypsum deposits are explored by bulldozing and diamond drilling. Bulldozers clear overburden from lateral exposures of the deposits, making them accessible for examination and sampling. Diamond drilling is generally on a grid pattern, with vertical holes at predetermined intervals over the various blocks or ore-bearing areas. Drilling is done well ahead of subsequent mining to properly evaluate underlying gypsum beds.

A gasoline-driven diamond drill is mounted on a wooden platform, which is bolted to a steel frame and skids. Ten-foot lengths of 2-inch pipe set in 12-foot lengths of 3-1/2-inch pipe, which butt against welded studs at each corner of the frame, form the stand. Upper ends of the 2-inch pipe are flattened and bolted to a piece of 3/4-inch steel plate, from which the sheave is suspended. The frame is constructed of angle iron and the skids of channel iron. The rig was designed and built by the company. A tractor quickly pulls it to the various drill sites, reducing moving and setting-up time to a minimum.

AX-size holes are drilled with 5- and 10-foot, rigid-type, double-tube core barrels. Cast-set or sinta-set coring bits are used.

Drilling through limestone ranges from 11 to 22 feet per shift, the slow progress being due to the ravelly and fractured character of the rock. Gypsum is penetrated rapidly with the drill in high gear and fast speed. Core recovery in limestone is 60 to 80 percent, full recovery usually being obtained in gypsum.

MINING METHODS

The gypsum deposits are mined by open-pit and underground methods. Quarrying is employed in areas where overburden and overlying strata are comparatively thin, and the underground room and pillar systems in areas where the depth of overlying formations will safely permit this method of mining.

Transmission lines are extended as close as possible to mine workings, and power is reduced through stationary and portable transformers from 4160 to 440 and 220 volts for use in loading equipment and drilling machines.

Open-pit Mining

The No. 10 area is an example of open-pit mining (fig. 4). Formations overlying the limestone above the No. 4 gypsum bed have been eroded, leaving a capping that ranges from 16 to 22 feet in depth. The underlying gypsum deposit ranges in thickness from 12 to 18 feet.

Waste-to-ore ratio in open-pit mining ranges from 1:1 to a maximum allowable limit of 1.5:1.

Open-pit quarrying is done by a bench method, stripping and mining being carried on simultaneously.

A series of vertical drill holes spaced on approximately 10-foot centers and in parallel rows 10 feet apart, depending on the depth and character of the rock, are drilled through the limestone. Fifty to 100 holes comprise a round.

Holes are drilled by a wagon drill mounting a 4-inch blower-type drifter. Drilling is dry; cuttings are removed from the hole by compressed air blown through the drill steel. Drill steel is 1-1/4 inch lugged, hollow round in 6-foot changes. Side-hole detachable cross bits are used, starting with the 2-3/4 inch size and with successive 1/16-inch reductions in gage. Compressed air is furnished by a 315 c.f.m., Diesel-driven, portable compressor. A miner and helper comprise the drill crew, working on the night shift and drilling 20 to 25 holes a shift. In places the dense, gray limestone is ravelly, which retards drilling progress. Illumination is supplied by a gasoline-driven, 1.5 kv.-a. portable light plant.

Holes in dense limestone are loaded with 1-1/4- by 8-inch cartridges of 65-percent ammonia dynamite. Electric blasting caps connected in series and using up to four delays are used for detonating. In ravelly and broken limestone a 20 percent-strength, free-running bag powder is used, detonated by electric blasting caps in cartridges of 65-percent dynamite.

Approximately one stick of dynamite is used per foot of hole drilled, with an over-all consumption in stripping of 1 pound per yard of limestone broken. The 65 percent-strength dynamite has a quick, shattering effect, thoroughly breaking the limestone. The broken rock remains more or less in place, making for easy removal by the power shovel.

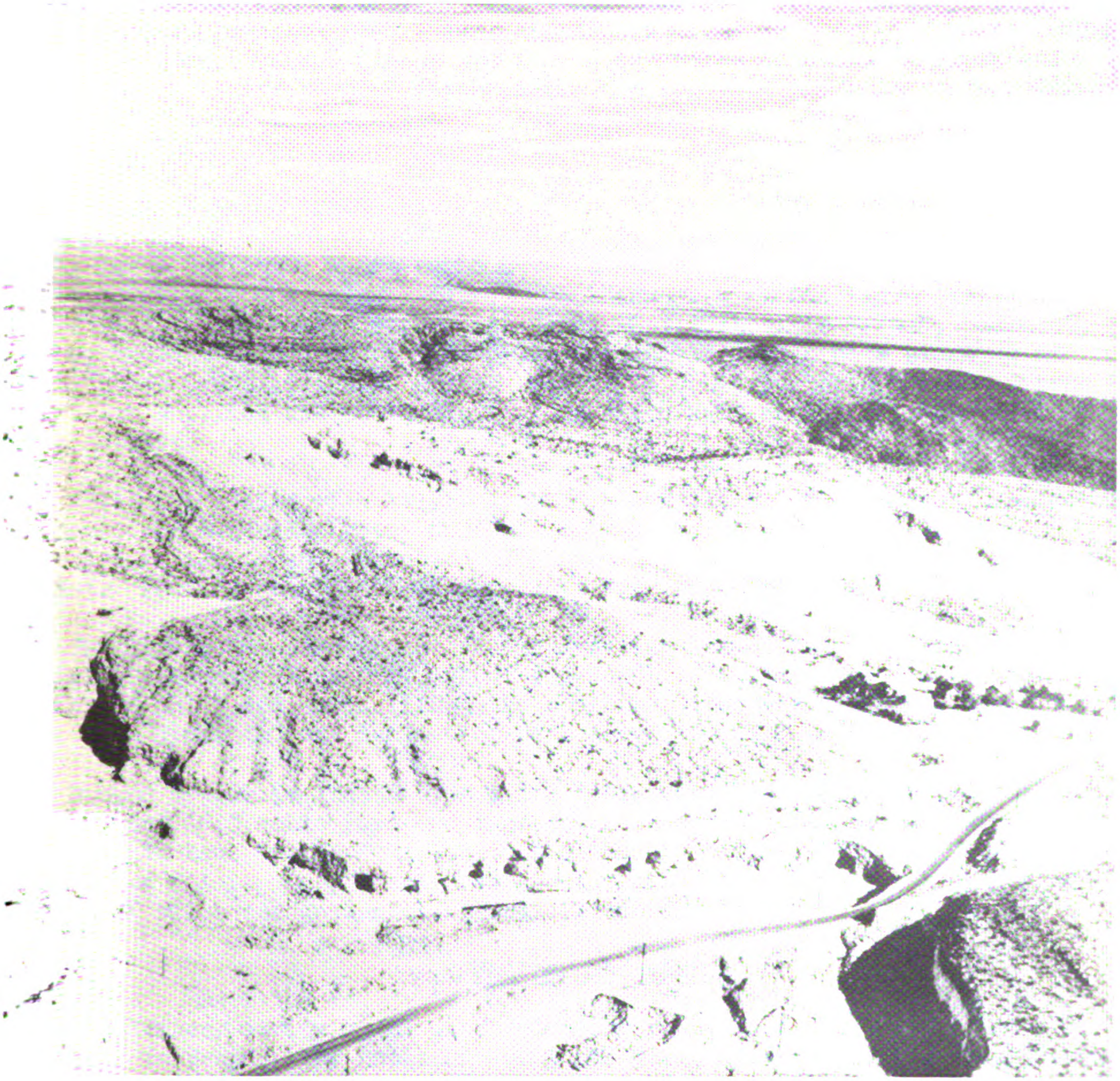

Figure 4. - No. 10 area, showing open-pit workings.

A 2-1/4 cubic yard electrically driven power shovel is employed to load broken limestone into 9.7 cubic yard end-dump trucks, which haul it to waste dumps. This haul is comparatively short, and 500 to 1,000 cubic yards of waste rock is removed daily.

The surface of the underlying gypsum bed, on completion of stripping, is cleaned by hand scraping and shoveling of any remaining limestone to prevent possible dilution of the ore. Vertical holes are then drilled on 3- to 4-foot centers and in parallel rows 3 feet apart to within 1/2 to 1 foot of the underlying limestone strata. Closer spacing of the holes increases fragmentation, and leaving a narrow band of gypsum along the footwall prevents further dilution. One hundred to 200 holes comprise a round, the usual blast being about 100 holes.

Jackhammers are used for drilling in areas where surface irregularities prevent efficient use of a wagon drill. The latter is used in comparatively level sections, where rapid set-ups can be made, and for deeper holes. Forty- to fifty-pound, blower-type, jackhammers and a wagon drill equipped with a 3-inch blower-type sinker are used. Drill steel is 1-inch, collared, hollow, hexagon threaded for side-hole, detachable, cross bits starting at 1-7/8 inches and 1/16-inch changes. One 210-c.f.m., portable, Diesel-driven compressor supplies air to the drills. A miner will average fifteen 16-foot holes a shift.

Holes are loaded with 1-1/4- by 8-inch cartridges of 65-percent ammonia dynamite, one cartridge being used per foot of hole drilled. Holes are connected in series and detonated electrically, up to 4 delays being used for a blast. Powder consumption in gypsum is 0.62 pound per ton.

The high shattering effect of the dynamite leaves but few large boulders requiring secondary blasting. About 3 percent of a blast requires blockholing, which is done by drilling the boulders with jackhammers, loading the holes with dynamite, and detonating with conventional fuse and cap.

Broken gypsum is loaded by a 1-1/2 cubic yard Diesel-driven power shovel into 9.7 and 10.0 cubic yard end-dump trucks and hauled to the crushing plant. This haul varies from 0.7 to 1 mile, and 500 to 900 tons of ore is transported daily. Dump trucks consume 2.5 gallons of Diesel oil hourly and average 10 miles per gallon of Diesel oil consumed.

Underground Mining

Preliminary stripping of overburden and removal of overlying strata are necessary to prepare the faces of No. 3 and No. 4 gypsum beds for underground mining. The North-South section on figure 3 indicates the original ground line and the area removed. The comparatively soft material above the No. 3 deposit and including the No. 2 bed is removed by power shovel or slusher to convenient stock piles and reloaded later into dump trucks and hauled to the crusher plant. Some blasting is necessary; powder consumption for this operation is 1 pound per cubic yard. The limestone strata above No. 4 bed is stripped by benching, similar to the method used in pit No. 10.

Headings on the No. 3 and No. 4 deposits are driven on approximately 35-foot centers, depending on the local condition of the overburden and thickness of the gypsum (fig. 5).

Deposits in the several areas present different mining problems. Portal widths are maintained 10 to 12 feet to give adequate support to the arch and overburden. Entries are widened to 20 to 22 feet as headings are advanced.

Height of the entries usually corresponds to the thickness of the deposits. A narrow band of gypseous clay overlying the No. 3 bed is tenacious enough to form a strong roof, and a narrow band of gypsum is left to help support the back of the No. 4 deposit. The sharp limestone-gypsum contacts form the footwall of each bed.

Several headings in a section are advanced with pillars left in a more or less regular pattern (fig. 3). Pillars range in size, depending on the condition of the roof and thickness of the gypsum, from 12 by 12 feet to 20 by 30 feet. Alternate sections between pillars are driven as headings and are advanced to form openings between entries. Headings vary in grade according to the dip of the deposit and have been driven for several hundred feet. Length of entries is contingent on effective limitations of loading equipment and the changing of gypsum to anhydrite.

Remaining pillars comprise 20 to 30 percent of the area mined. Under good conditions, 80 percent of the gypsum is recovered, but in sections of bad ground and weak roofs larger pillars are left for adequate support.

Occasional use of timber is required to catch up slabbing roofs and in areas weakened by solution cavities.

A V-cut round is used in driving headings (fig. 6). Forty to 80 holes comprise a round, depending on the size of the entry, with a usual advance of 10 feet. Close spacing of holes insures fine breaking of the gypsum. Entries range in width from 10 to 22 feet and in height from 12 to 18 feet.

Holes are drilled by 1-1/2-horsepower electric post drills using 1-1/2 inch auger steel in 4-foot changes up to 18 feet, equipped with 1-5/8-inch, U-shaped, tungsten-carbide, insert-type cutting bits. Drills are mounted on 2-1/2 inch square, ratchet-type columns or posts. A miner and helper comprise a drill crew that drills 30 to 40 twelve-foot holes a shift (fig. 8). Two crews usually work in an entry, one on each side of the face.

Holes are loaded with 1-1/4- by 8-inch cartridges of 65-percent ammonia dynamite and detonated by conventional fuse and cap or electrically. Fuse and caps are used when starting narrower headings at the portal and electric detonation in wider entries. Holes are connected in series, four delay electric blasting caps being used. Powder consumption for underground work is 1.43 lb. per ton.

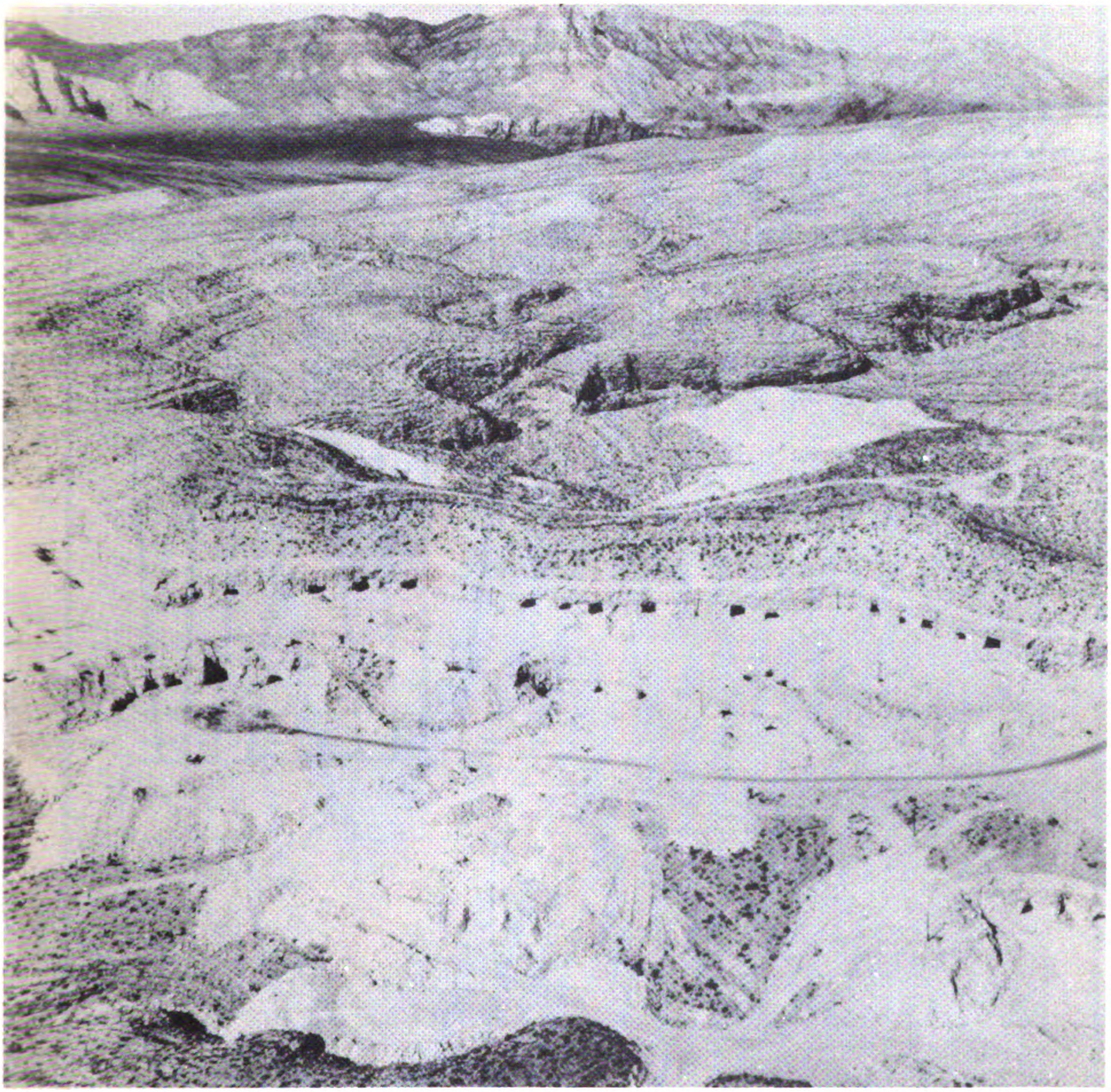

Figure 5. - No. 4 area, showing entries in Nos. 3 and 4 gypsum beds.

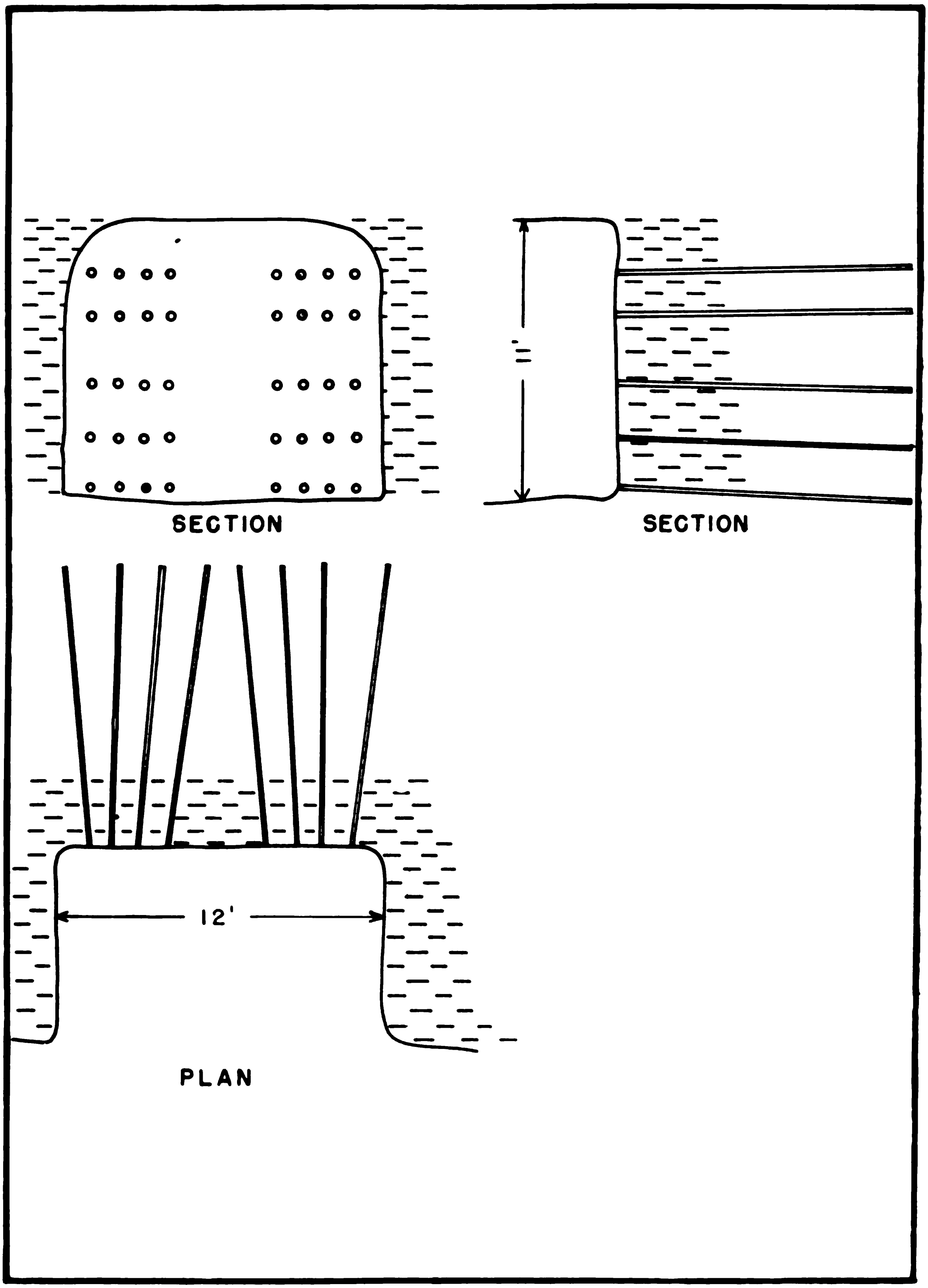

Figure 6. - Plan and sections of drill rounds used in starting entries.

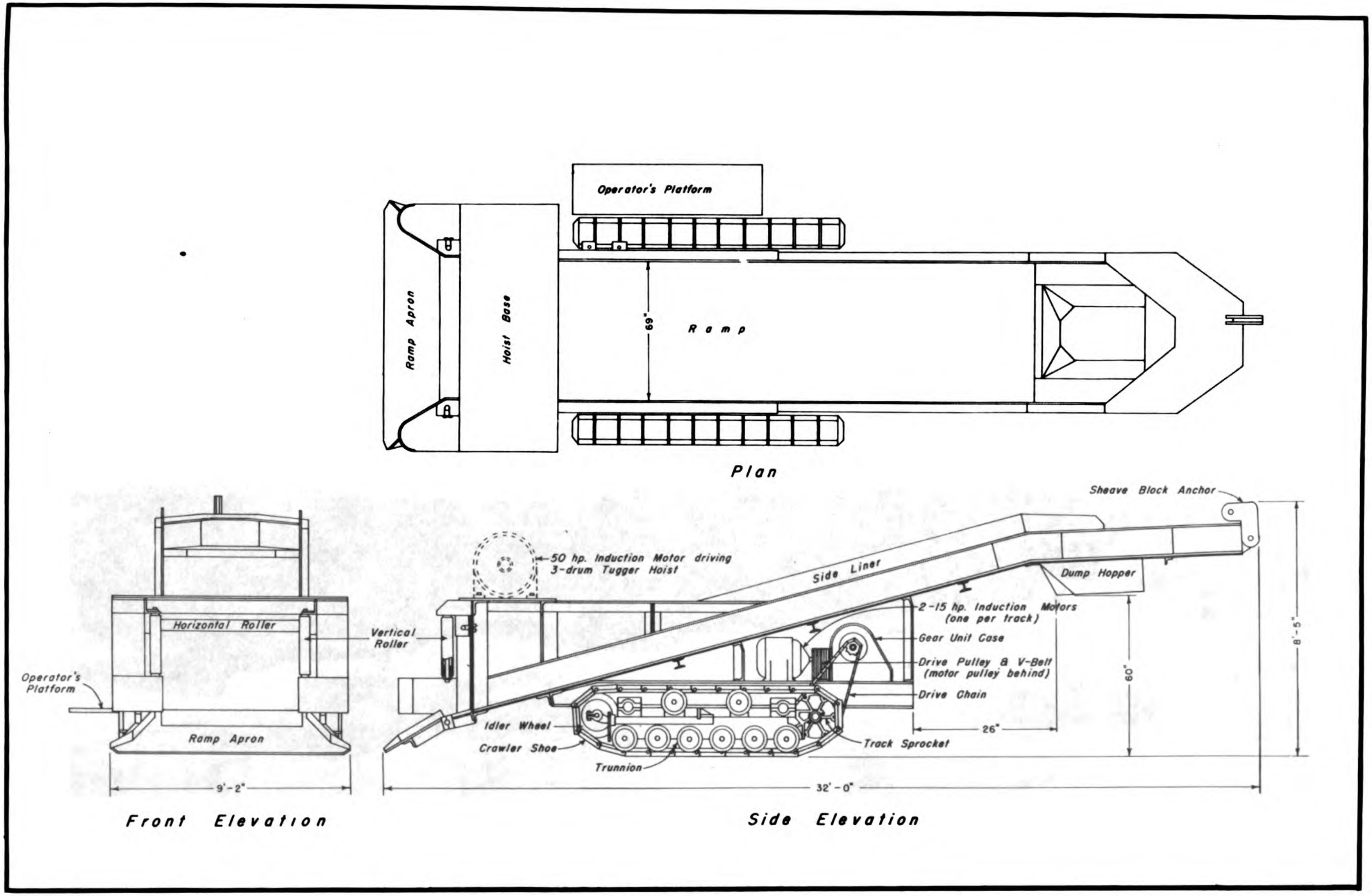

Figure 7. - Plan and elevations of scraper loader.

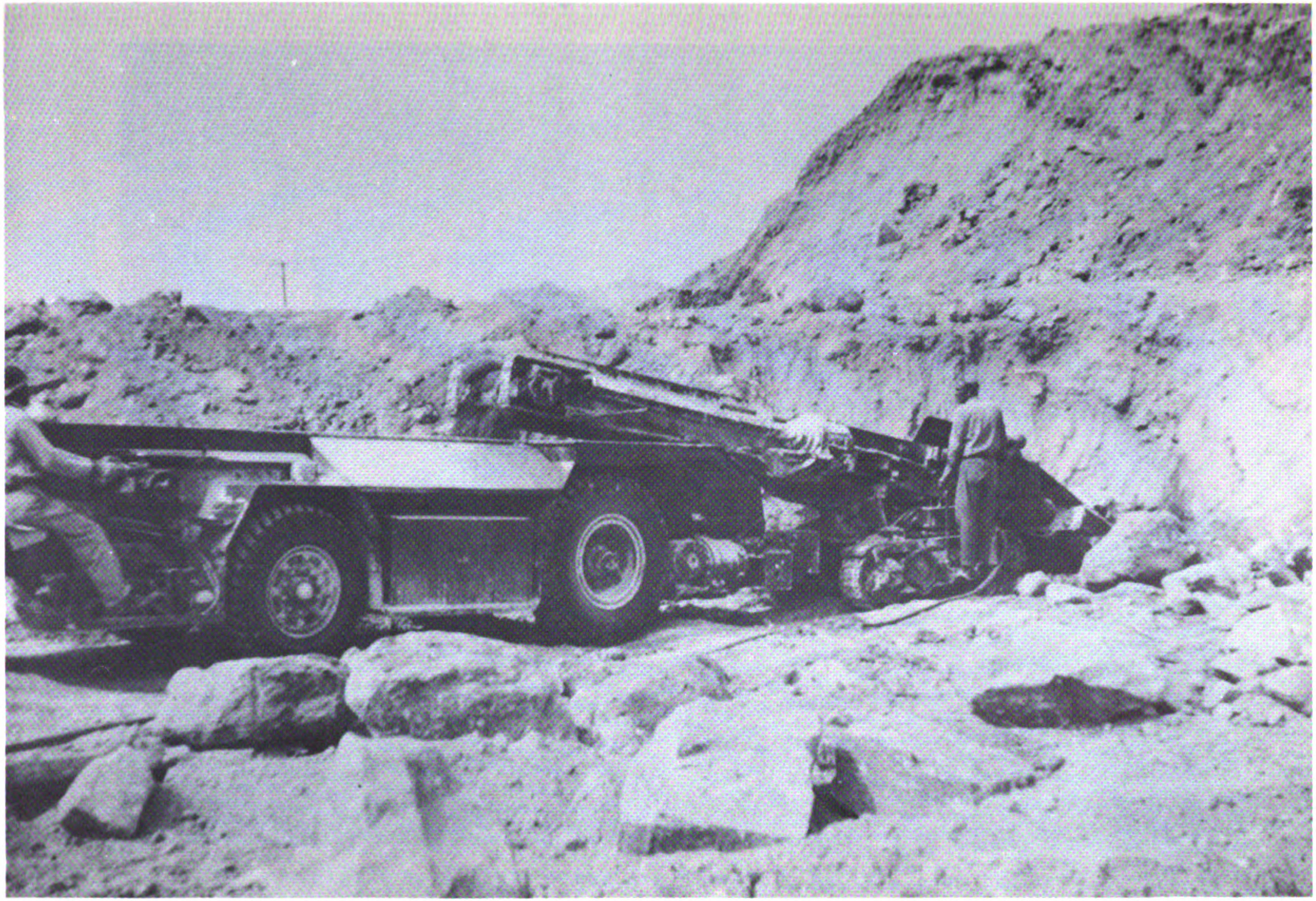

Figure 8. - Rock loader and shuttle car.

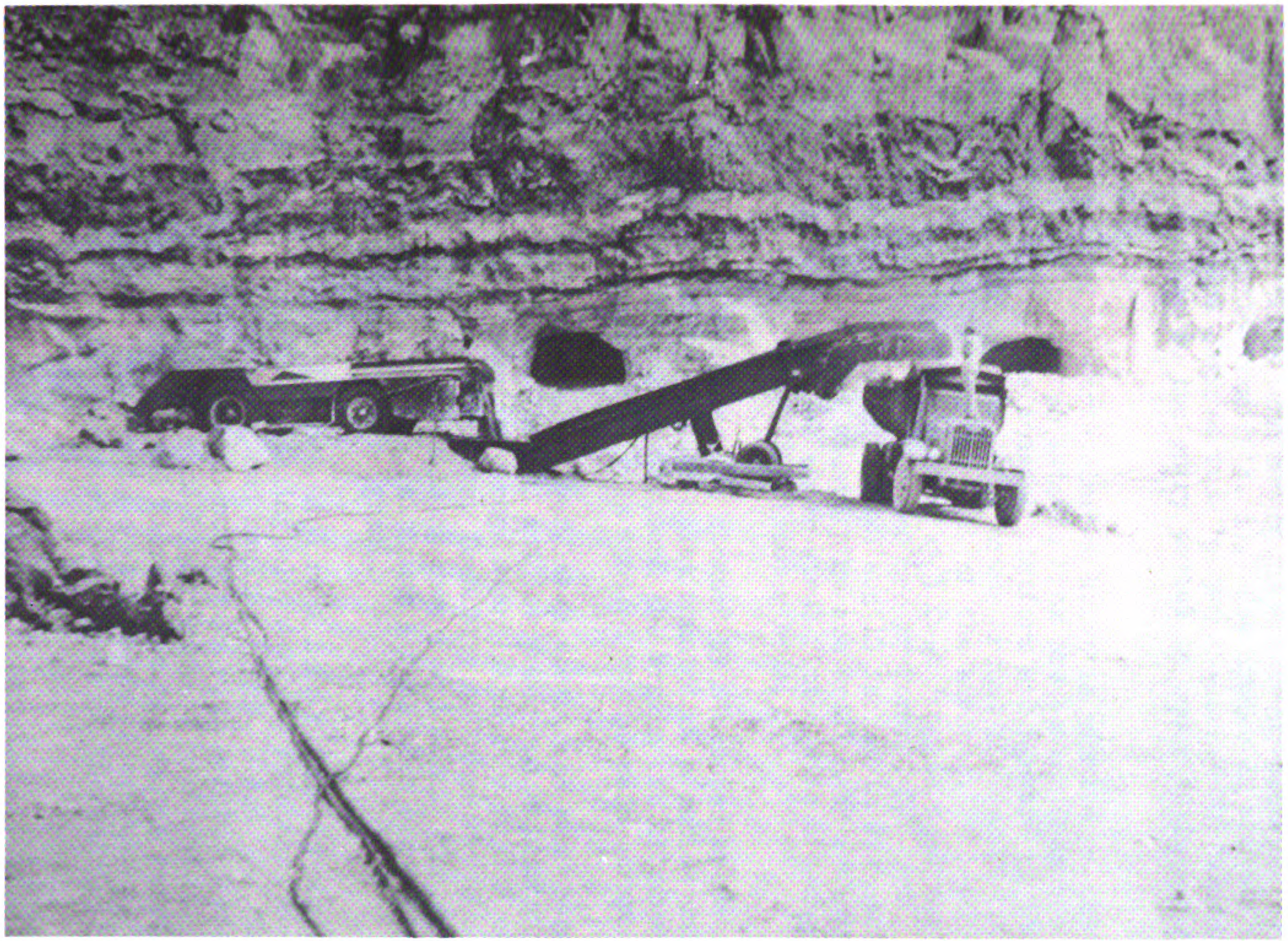

Figure 9. - Shuttle car and elevator, No. 3 gypsum bed.

Loading

Broken gypsum is removed by scraper loading or rock loader and shuttle cars. Scraper loading has been used for several years, having superseded the track and mine car system. The scraper loader is a compact self-propelled unit comprising an inclined slide terminating in a loading platform, under which trucks are spotted for loading (fig. 7). The loader is mounted on 12-inch crawler tracks, which are chain-driven by two 15-horsepower motors, and is usually set on a ramp close to the entry portal in order to insure adequate headroom for the trucks.

A 50-horsepower, 3-drum, electric slusher hoist is mounted on the frame above the scraper slide. A pull rope extends from the center drum back over a sheave attached to the end of the loading platform and forward to the scraper. Tail ropes run from the two outer drums around sheaves anchored in opposite sides of the heading and to the back of the scraper. A 1-ton-capacity hoe-type scraper 5 feet wide by 2 feet high by 5 feet long is used and has proved effective in wide entries. Wire ropes are preformed, 5/8-inch, 6 by 19, hemp center, and sheaves or snatch blocks are 12 inches in diameter. Pin holes for anchoring the wedge-shaped sheave pins are drilled by a hand-held electric auger drill, using 2-1/2 inch auger steel fitted with a 4-edge tungsten carbide cutting bit set to bore a 3-inch diameter hole.

Longer crosscuts between headings are cleaned by a scraper operated from a 50-horsepower, 3-drum, electric slusher hoist mounted on a mobile unit. The mobile slusher is moved into the entry, and the broken ore is scraped from the crosscut to the entry, where it is handled by the main scraper loader.

Advantages of scraper loading are lower labor costs, one-man operation, faster mucking, portability of the loader, and low power and maintenance costs. Disadvantages are excessive wire rope wear, limited range of operation, difficulty in angling into crosscuts, inability of operator to see scraper at heading, and necessity of building ramp for loader. The effective limit of the scraper loader is 125 feet, although it has been used for distances up to 200 feet with no limitations as to grade.

A continuous-type, electrically operated rock loader used in conjunction with two shuttle cars and a portable loading elevator was purchased recently by the company for underground loading and hauling (figs. 8 and 9). The initial cost of this equipment is high in comparison with scraper loaders but is offset by lower operating costs and higher rate of production. Loader and shuttle cars are extremely mobile and flexible units, easily moved to various headings and crosscuts, and having a wide range of operation, limited only by length of cable on shuttle-car reels and grade of the entries. Maximum working grade is 6 percent.

The loader is a self-propelled, high-capacity, continuous-type loading machine mounted on caterpillar treads. A loading head carrying two gathering arms crowds into the muck pile. The arms, working with a crablike action, dig into the broken ore, pulling the material onto the loading head. A chain-and-flight conveyor carries the rock up and over the loader, dumping it into a shuttle car. A 75-horsepower motor that works through a gear reducer drives the gathering head and caterpillar treads; the conveyor is operated by two

7.5-horsepower motors. A 5-horsepower motor on a hydraulic system raises and lowers the gathering head, permitting it to follow rough bottoms. The boom can be swung 45 degrees to either side of center. Rock up to 30 inches maximum size can be handled. Rate of production depends on length of haul, number of entries mucked, and availability of dump trucks for the crushing-plant haul. Current production rate is 500 tons daily.

The shuttle car is a flexible, heavy-duty machine mounted on pneumatic tires and capable of hauling an 11-ton load of broken gypsum. As the loader discharges ore into the shuttle car, a motor-driven, doubles chain, flexible conveyor that extends along the bottom of the car moves the muck forward until loading is completed. The shuttle car transports the ore to the loading elevator or dump trucks, where it is quickly emptied by the forward motion of the conveyor. Cars are equipped with dual controls, never have to be turned around, and when working in pairs greatly expedite loading and hauling. Operating range depends on the length of cable, which winds in and out of the hydraulic cable-reel attached to the car. Two 10-horsepower traction motors drive the car, and a third 10-horsepower motor operates the conveyor.

Ore from the shuttle car is dumped into the hopper of the inclined elevator loader and is fed by a double-chain flexible conveyor to dump trucks spotted beneath the discharge end. A 25-horsepower motor drives the conveyor.

Equipment

A list of principal equipment used in mining and hauling follows:

2	Wagon drills
	Hand-held drills.
	Electric auger drills
	A6 post drills
	Carbide inserts
	Cutting bits
1	Diamond drill
1	315 c.f.m., Diesel-driven, portable compressor
1	210 c.f.m., Diesel-driven, portable compressor
1	105 c.f.m., gasoline-driven, portable compressor
1	2-1/4-yd. power shovel
1	1-1/2-yd. power shovel
2	Bulldozers
3	9.7 cu. yd. end-dump trucks
2	10 cu. yd. end-dump trucks
1	1.5 kv.-a. portable light plant
1	Continuous-type loader
2	Shuttle cars
1	Elevator
2	Slusher loaders equipped with 3-drum slusher hoists
1	Truck-mounted, 3-drum slusher hoist
1	Motor-generator set
1	200-amp., electric welder
1	Crane
1	Portable, 15-kw., generating power plant

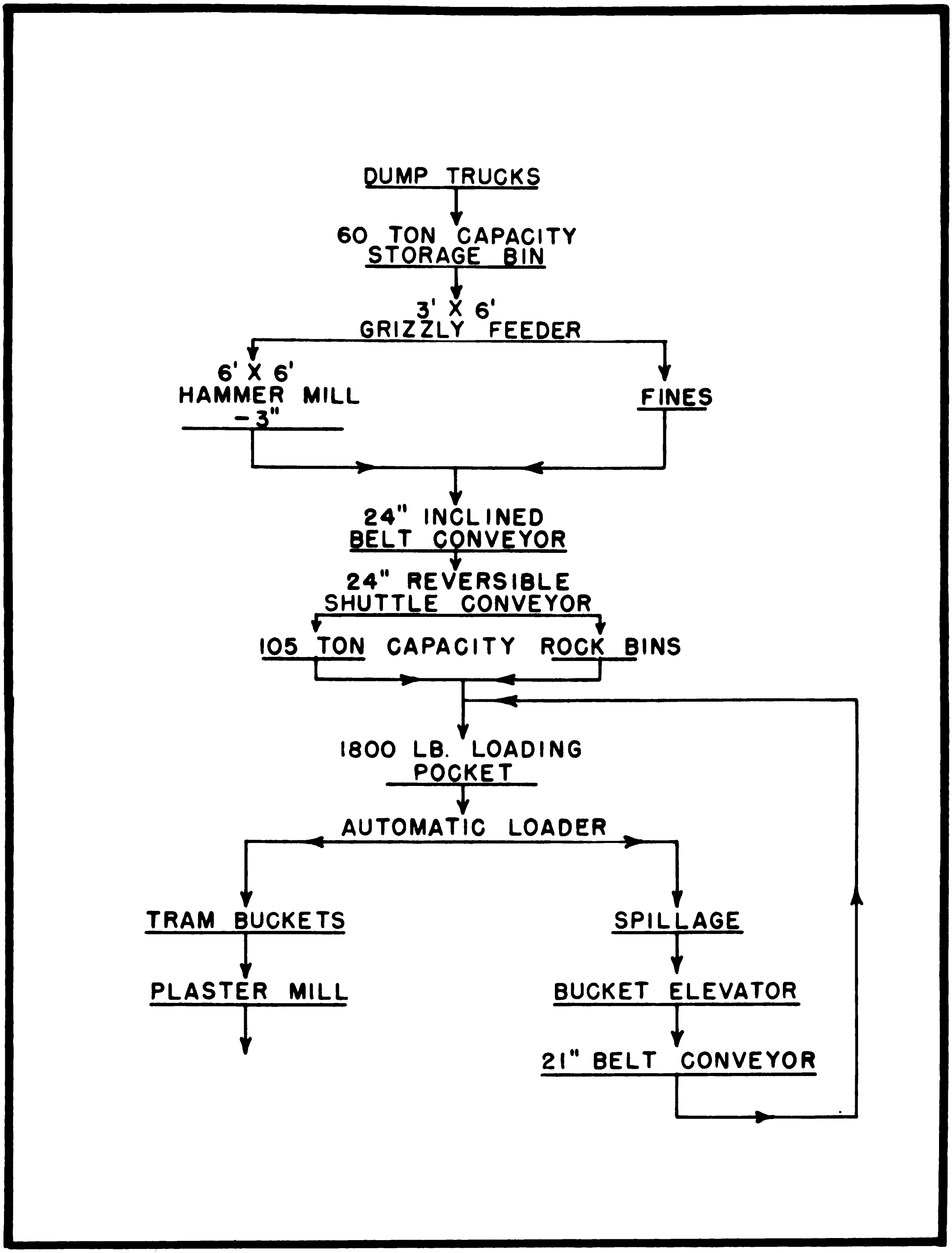

Figure 10. - Flow sheet of crushing plant and tramway loading terminal.

1 Patrol road grader.
1 Oil service truck.
1 1-1/2 ton power-wagon repair truck.

A well-equipped machine shop housed at the mine in a quonset building maintains repairs on mining and hauling equipment.

Diesel oil is delivered in tank cars and pumped directly to mine storage tanks.

CRUSHING PLANT

Ore is dumped from trucks into a 60-ton-capacity storage bin and is fed by grizzly feeder to a hammer mill set with a 3-inch discharge opening (fig. 10). Fines drop between grizzly bars to a belt conveyor and form a protective cushion against the coarser material from the hammer mill. The inclined belt conveyor carries the crushed ore to a shuttle belt conveyor, which transfers it to two 105-ton-capacity steel rock bins above the tramway loading terminal.

The grizzly feeder and conveyor belts are motor-driven; the hammer mill is flat belt connected to a 200-horsepower motor.

TRAMWAY

The twin-cable continuous tramway, which extends from the crushing plant to the plaster mill, is 3,600 feet long and comprises two sets of parallel track cables, one pair above the other, supported by 11 towers. Elevation at the loading terminal is 4,216 feet, and at the discharge end it is 3,463 feet. Loaded tram cars travel on the upper cables, and inverted empty cars return on the lower set. A traction wire rope driven by a 35-horsepower motor is permanently attached to the bottom of each car and passes over grip sheaves at loading and discharge terminals. Track cables are 1-1/4 and 1 inch smooth coil, and the pull wire rope is 7/8-inch, 6 by 19, hemp-center construction. The shallow, 18 cu. ft. capacity, steel tram cars are rectangular, supported by two wheels on each side, weigh 500 pounds, and carry an 1,800-pound load. The tramway carries 40 tram cars and has a capacity of 120 tons an hour.

Ore is passed from rock bins through a pneumatically controlled chute gate to an 1,800-pound-capacity measuring pocket. Empty tram cars pass under the hopper, releasing a mechanical tripping device that opens the loader door, dropping the ore into the moving car. Counterweights on the loader door swing it back to the closed position.

The spillage from automatic loading drops to a bucket elevator and is carried by a 21-inch belt conveyor back to the loading pocket.

Equipment (fig. 10)

Major equipment at the crushing plant and loading terminal comprises:

1 4 by 7-1/2-foot grizzly feeder.
1 31-1/4 by 42-inch-opening hammer mill.
1 350 c.f.m. stationary compressor, motor-driven.
1 300-amp. electric welder.
1 Tramway complete with operating equipment.

PLASTER MILL

Ore discharged at the tramway unloading terminal passes over a double-deck vibrating screen fitted with 1-inch and 1/4-inch screens, or goes direct to conveyor belts and four storage bins (figs. 11 and 12). Hardwall-grade gypsum is screened; the minus 1-inch plus 1/4-inch product passes to a rock bunker, from which it is loaded into railroad cars for shipment to Portland cement plants. About 150 tons is shipped daily. The plus 1-inch and minus 1/4-inch sizes are carried over conveyor and shuttle belts to the Hardwall storage bin. Casting and stucco grades are not screened but are conveyed directly to storage bins or by-passed to stock piles.

Grinding

Ore from the storage bins is fed through pneumatically controlled feed rolls to three roller-type grinding mills operating in closed circuit with cyclone double-cone separators (fig 13). Two older units have capacities of 9 tons an hour; the third unit, equipped with a whizzer separator as an integral part of the mill, has a 12-ton hourly capacity. Casting and hardwall grades are ground so that 75 to 78 percent will pass through a 100-mesh screen, and the stucco grade is ground so that 85 to 88 percent passes through a 100-mesh screen.

Ground gypsum is drawn from the cyclone separators and transferred through screw conveyors to land-plaster bins, where it is stored preparatory to calcining. An exception is a product used for agricultural purposes, which is passed through screw conveyors directly to a bagging machine. This agricultural gypsum is casting-grade material (+78 percent $CaSO_4$) ground so that 90 percent passes through a 100-mesh screen.

Calcining

The calcining process, in which part of the water of crystallization is driven from the raw gypsum, is accomplished in four 20-ton-capacity kettles (fig. 14). ($CaSO_4.2H_2O$ + heat = $CaSO_4.1/2\ H_2O$.) These kettles comprise a cylindrical steel shell 3/8 inch thick, 10 feet in diameter, and 12 feet long set vertically on an iron lip ring over the fire box. The kettle bottom is a one-piece, convex, steel plate 1-1/4 inches thick placed so that it is arched over the combustion chamber. Firebrick masonry supports and surrounds the kettle, leaving a circular space between the shell and firebrick. Four horizontal cross flues arranged in pairs, one set above the other, pass through the shell. Baffles direct heat from the kettle bottom around the shell, through the cross flues, and out the exhaust stack. Kettle shells average 4 to 5 years' operation and kettle bottoms 1 to 2 years' service.

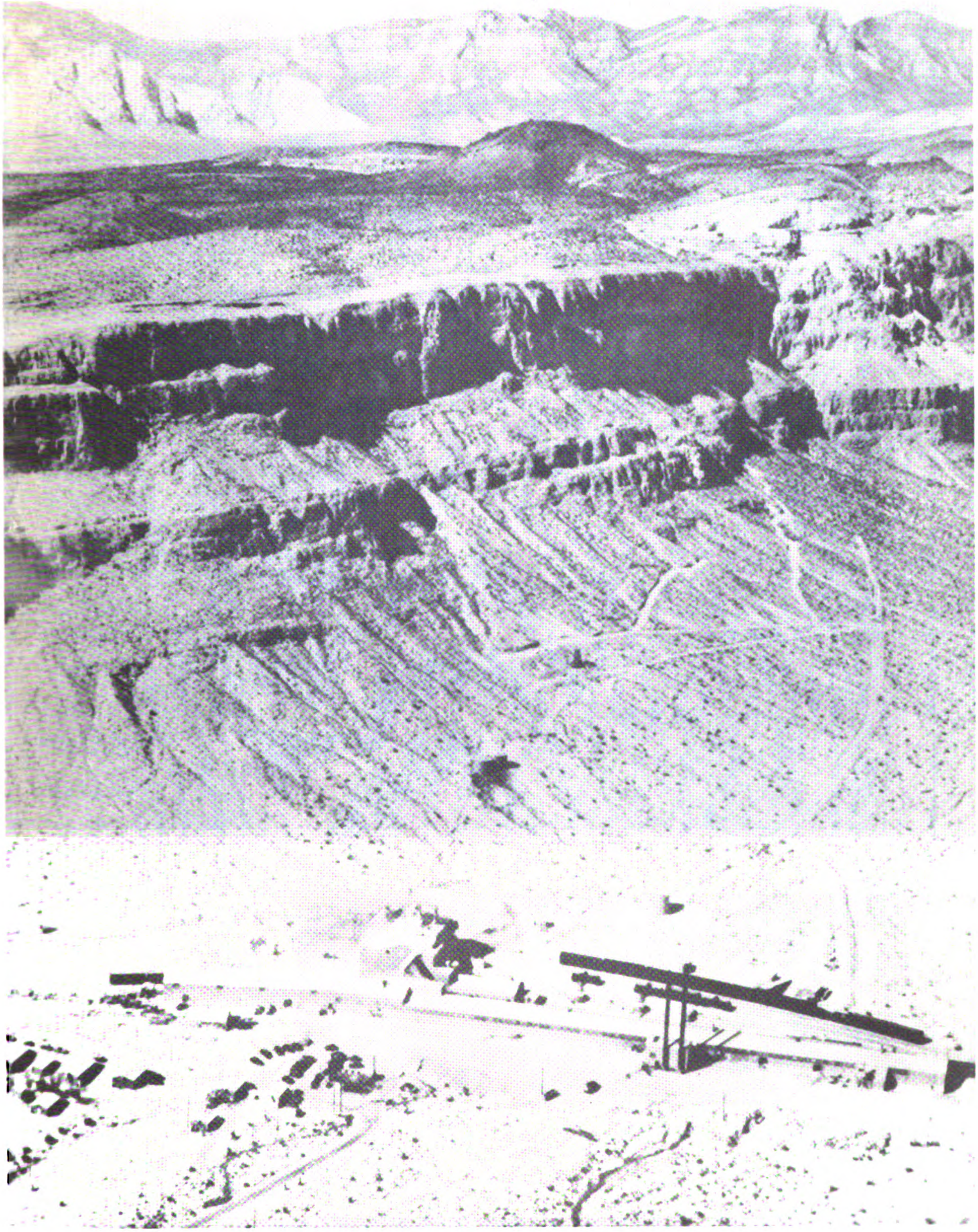

Figure 11. - Plaster mill, board plant, and tramway.

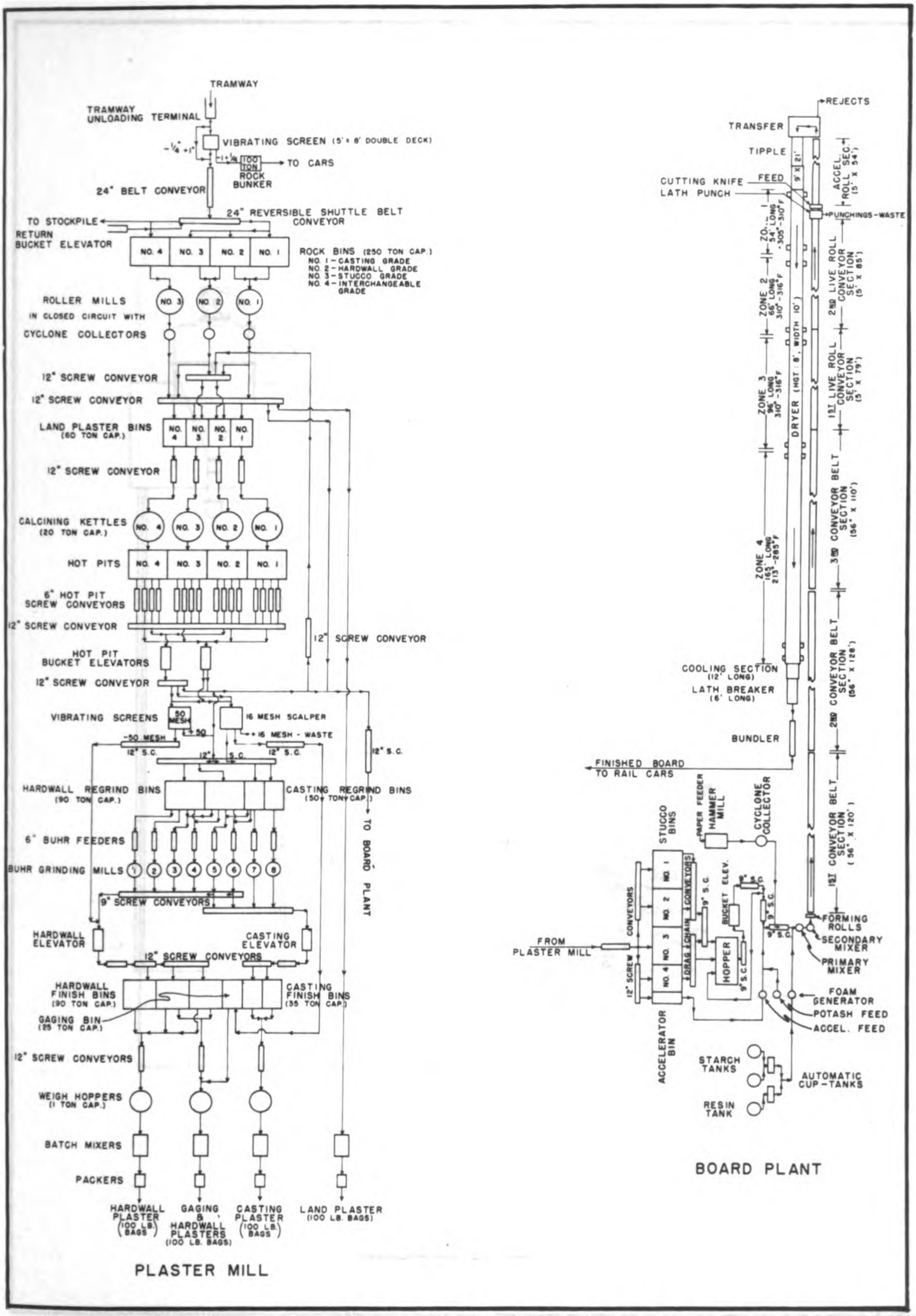

Figure 12. - Flow sheets of plaster mill and board plant.

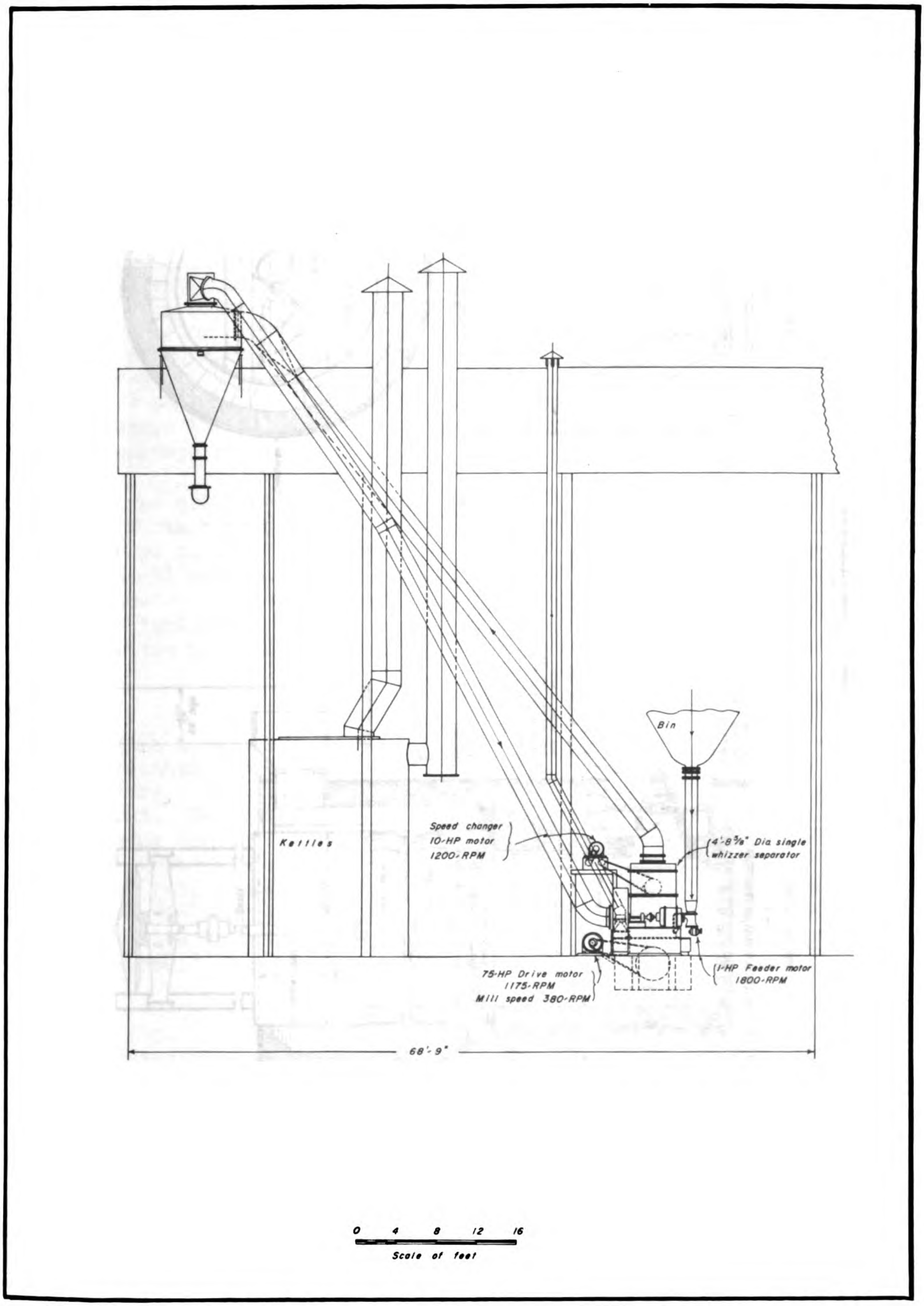

Figure 13. - Side elevation of roller mill and cyclone collector.

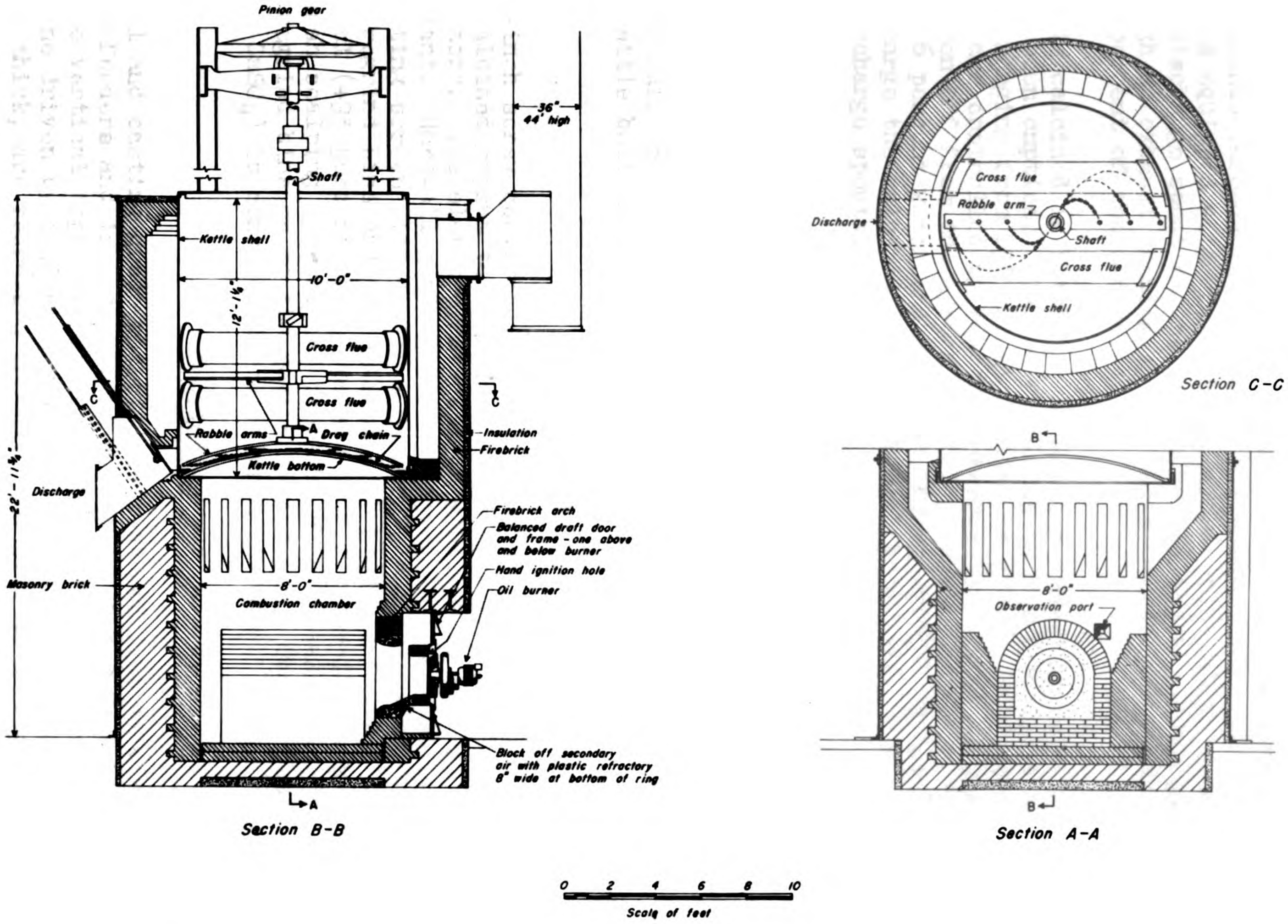

Figure 14. - Generalized sections of a gypsum calcining kettle.

Raw gypsum is fed into the kettle through charging spouts by screw conveyors. The charge is agitated continuously by horizontal rabble arms, above, between, and below the cross flues, attached to a vertical pinion gear-driven shaft that extends through the center of the kettle. The bottom set of rabble arms is equipped with drag chains, which sweep calcined material through the discharge spout at the bottom of the shell. Steam and dust are vented through an exhaust opening in the kettle cover. Dust and water loss is about 18 percent of the charge.

Gypsum is calcined in batches; the kettles loaded as soon as previous charges have been emptied. Time of calcining is 2-1/4 to 2-1/2 hours at temperatures ranging from 230° F. at loading to 350° F. at completion. Temperatures are controlled by electric pyrometers. About 75 percent of the water is driven off from the gypsum in this process, leaving a product containing 5 to 6 percent water and known as "first settle" calcined gypsum. Kettles discharge the calcined gypsum into hot pits built adjacent to and below the discharge spouts.

Kettles are oil-fired; oil is preheated by steam to 100° F. in a 20,000-gallon tank, further preheated to 160° F. in a smaller tank, and fed to the kettles under 90 to 100 p.s.i. pressure through an electrically controlled oil burner. Fuel-oil consumption is 7.5 gallons per ton of calcined gypsum or plaster produced. A standby Diesel generator is maintained as a protection against power failures. Unloading of the kettles is essential to prevent warping of kettle bottoms and settling of the charge.

Screening

Four 6-inch screw conveyors in the bottom of each hot pit carry the pulverized calcined gypsum to a 12-inch screw conveyor, which delivers it to bucket elevators. The elevated material is screened or conveyed directly to the board plant. Hardwall-grade calcined gypsum (+90 percent $CaSO_4$) passes over a vibrating screen fitted with a 50-mesh screen; the oversize is conveyed to hardwall regrind bins and the undersize to hardwall finish bins. Casting-grade material (+93 percent $CaSO_4$) passes over a vibrating screen equipped with a 16-mesh scalping screen; the oversize goes to waste and the undersize to casting regrind bins or to the gaging finish bin. Stucco-grade gypsum (+85 percent $CaSO_4$) is conveyed directly from elevators to the board plant.

Regrinding

Hardwall and casting grade material is conveyed from storage bins by 6-inch screw feeders and is reground in a battery of 8 Buhr mills. These mills are the vertical type, comprising a fixed circular granite stone and a rotating stone driven by a 30-horsepower motor. Stones are 3 feet in diameter and 5 inches thick, are redressed monthly, and give an average service of 18 months. Capacities range from 1-1/2 to 2-1/2 tons hourly, grinding the hardwall grade so that 90 percent will pass through a 100-mesh screen and the casting grade so that 98 percent passes through a 100-mesh screen. A grade of product is obtained by the Buhr-mill method of regrinding that is not produced by other grinding machines.

The reground gypsum is fed by screw conveyors to bucket elevators and carried to hardwall and casting finish bins.

Mixing and Packing

Plasters are drawn from the finish storage bins by screw conveyors and are batch-loaded in weigh hoppers. The cone-shaped steel hoppers are 6 feet in diameter, 5 feet high, suspended on beam scales. The usual charge is 1 ton of plaster plus weighed quantities of accelerator or retarder and fiber. The commercial retarder is derived from slaughterhouse tankage, and the accelerator is ground raw gypsum.

Accelerators and retarders are added to plasters to speed or slow the time of initial set. Determined amounts can be added to obtain any desired setting speed. Chopped sisal fiber is added to act as a binder to the fiber-grade plaster.

The contents of the weigh hopper are dropped into a batch mixer, where they are thoroughly mixed for 2 minutes by two sets of paddles attached to parallel horizontal shafts and rotating in opposite directions.

The mixed product is discharged to an automatic packer, which fills multiwall-type paper bags with 100-pound charges.

Products

The principal plaster products produced are fibered hardwall plaster, unfibered hardwall plaster, casting plaster, and gaging plaster. Special fast- and slow-set and dental plasters are produced in smaller quantities.

Equipment (fig. 12)

Principal milling equipment is:

1 5- by 8-foot, F600, double-deck vibrating screen.
3 Roller mills and Cyclone separators.
Pneumatic feed controls.
4 Calcining kettles equipped with Ray oil burner, size 8, type AG14
4- by 6-foot Hummer vibrator screens.
8 Buhr mills.
Baggers
6- and 12-inch diameter covered screw conveyors.
Steel suspension-type storage bins equipped with electric vibrators.
Convey. bucket elevators.
1 30-kw. Diesel generator

BOARD PLANT

The board plant is just south of the plaster mill. Stucco-grade calcined gypsum is carried by screw conveyors from the hot pits to four storage bins in the board plant and discharged to drag-chain conveyors, which transport the material to a hopper (figs. 11 and 12). Measured quantities of potash and accelerator are added to the feed, which is conveyed to the primary mixer.

Starch and resin are fed from storage tanks through automatic cup feeders to a foam generator, which discharges its product to the primary mixer. Fibrous, unsized paper is pulverized in a hammer mill in closed circuit with a cyclone separator. The primary or agitating mixer mixes the hopper feed, foam, paper, and water and passes it on to the secondary or spindle mixer.

Slurry from the secondary mixer is discharged on a layer of paper that is being fed continuously to a set of forming rolls. The rolls distribute the mix over the paper to a determined thickness and press a second layer of paper, which passes under the upper roll, on top of the mixture. Rolls form three rows of 16- by 3/8-inch lath simultaneously, or one row of 48 by 3/8 or 1/2 inch wallboard.

Edgers placed ahead of the rolls overlap edges of the bottom paper and cement edges of the upper paper, which, when passed between the rolls, make a sealed round edge on the lath.

Continuous strips of lath or wallboard produced by the forming rolls travel over a series of conveyor belts and live rolls to the lath punch and cutting knife. The board sets hard enough during the period of travel to permit punching and cutting. The three conveyor-belt sections comprise endless flat belts supported by 3-inch-diameter, rubber-covered idlers spaced on 1-foot centers. Return idlers are on 10-foot centers. The two live roll sections, which permit circulation of air around the drying plasterboard, comprise 3-inch diameter rollers spaced on 1-foot centers. Alternate rollers are driven by chain and sprockets. Total length of the conveying system is 560 feet.

The 3/8-inch lath is fed continuously by the live rolls to an automatic punch, which perforates it with 3/4-inch holes. Holes accelerate drying and constitute the necessary key for subsequent coats of plaster. Punchings from the holes are conveyed by belt conveyor and bucket elevator to a waste bin. Wallboard and standard lath are not punched.

Strips of lath continue to an automatic cutting knife that partly severs the first two 4-foot lengths, completely cuts the third 4-foot length, and thrusts the 12-foot strip onto the accelerating rolls, which quickly carry it to the transfer. Wallboard is cut in 4-, 8-, and 12-foot lengths.

The accelerating roll section consists of 3-inch diameter chain and sprocket driven brass rolls spaced on 1-foot centers. The greater speed of these rolls prevents a pile-up of the strips behind the cutting machine.

The transfer is an electronically controlled, pneumatically operated machine comprising a series of brass rolls spaced on 1-foot centers, on which strips from the accelerating section are rolled. A set of transversely moving, 4-1/2-inch, woven belts between the rolls is raised by compressed air-operated cylinders, which lift the 12-foot strips from the rolls and carry them across the transfer, where the process is reversed. The transverse belts lower the strips to a series of chain and sprocket-driven rolls, which convey them to the tipple.

The tipple is a mechanically operated machine consisting of ten 4-inch woven belts that travel over 3-inch live rolls spaced on 13-1/2-inch centers. Pivoted at the back, its forward end is raised and lowered through a 45-inch vertical distance by electronic controls and stops at each of the six sets of dryer rolls and propels the strips of lath or wallboard onto these rolls.

Racks extending through the length of the dryers contain six parallel tiers of chain- and sprocket-driven rolls 9 inches apart vertically. Steam pipes run between rolls and along the top and bottom of the dryers.

The dryer comprises four enclosed sections made up of sets of individual 6-foot sections in 54-, 66-, 96-, and 168-foot connected lengths. Temperature ranges in each section are:

Sec.	°F.
1.......	310-305
2.......	316-310
3.......	316-310
4.......	285-212

The dryer removes about 6,000 pounds of excess water per 1,000 square yards of lath and 600 pounds per 1,000 square feet of wallboard. Exhaust fans draw moist air from each section.

As the dried lath and wallboard are too hot for handling when they emerge from the dryer, they are passed through a 6-tier, open cooling section, which pushes the strips over live rolls to the breaker. The breaker, a 6-tier machine, breaks the 12-foot strips of lath at the partly severed 4- and 8-foot marks, producing three 4-foot lengths of the finished product. Wallboard over 4 feet in length passes through the inactive machine.

Travel time from forming rolls to breaker is 1 hour for 3/8-inch lath and 1 hour 40 minutes for 3/8-inch wallboard. Products are rigidly inspected; lath and wallboard not conforming to specifications are discarded.

Laths are carried by hand and stacked on the bundler in piles of five, their long edge parallel to the line of travel. As the stacks move over rollers to the discharge end, a 2-inch strip of gummed tape bearing the company label and specifications is mechanically pasted over the short edges of the bundled laths. A sealed bundle of 3/8-inch laths comprises five 4-foot by 16-3/8-inch pieces having a surface area of 3 square yards.

Wallboards and bundled laths are loaded manually on gasoline-driven fork trucks and carried directly to rail cars or stock piles.

The board plant production rate is 50,000 to 60,000 square yards of 3/8-inch laths in 24 hours, or 152,000 square feet of 3/8-inch wallboards in 12 hours.

Specifications for the 3/8-inch lath and 4-foot by 3/8- and 1/2-inch wallboard conform to A.S.T.M. requirements.

Equipment (fig. 12)

Principal equipment in the board mill comprises:

- Lath punch
- Cutting knife
- Forming rolls, transfer, and tipple
- Dryer equipment
- 142 c.f.m. and 284 c.f.m. compressors
- Gasoline-driven fork trucks

BOILER PLANT

The power plant is housed adjacent to the board plant and comprises two oil-fired, horizontal-type steam boilers having normal ratings of 177 and 230 horsepower, which supply 10,600 and 13,800 pounds of steam hourly. The boilers are operated at 200 percent of their normal rating. Fuel oil is preheated to 160° F. and fed to boilers under 60 p.s.i. pressure; steam is delivered to the board plant dryer circuit at 177 p.s.i. pressure. Oil consumption is 96 gallons per 1,000 square yards of 3/8-inch laths produced, or about 5,000 gallons daily.

Condensate from the dryers is returned to the boilers by a special-type centrifugal pump; make-up water is added by double-acting boiler pumps. Water is preheated and softened.

Fuel oil is delivered in tank cars and unloaded by gravity into two 20,000-gallon storage tanks, or pumped to a reserve 100,000-gallon storage tank.

Equipment

Major boiler-plant equipment consists of:

- Stirling type boilers
- Oil burners
- Centrifugal and double-acting boiler pumps

ORGANIZATION

Company organization at Blue Diamond consists of a works manager, who directs all phases of the company's operation; an office manager; a mine superintendent responsible for all mining operations; a mill superintendent in charge of the plaster mill and board plant; and a maintenance superintendent in charge of all maintenance work. Foremen and shift bosses are under the superintendents' direction.

A modern office building at the plant houses the works manager, office manager, and clerical staff; the superintendents have offices at the mine and mill.

A complete analytical laboratory under the supervision of a chief chemist is situated adjacent to the mill.

A general warehouse with space for storage of roll paper and chemicals occupies the west end of the board plant.

Major mechanical and electrical repairs are made in a well-equipped machine shop. This shop and a truck repair shop are near the plant.

WAGE SCALES

The following was the prevailing hourly wage scale, April 1949:

Mine and quarry:

Shovel operator	$1.90
Crane, blade, and tractor operator	1.75
Hoistman, electric	1.65
Powderman	1.65
Diesel-truck driver	1.60
Tram operator	1.60
Truckdriver	1.40
Miners	1.40
Rock-loader operator	1.80
Shuttle-car operator	1.60
Crusher operator	1.37-1/2
Mucker	1.32-1/2
Laborer	1.32-1/2

Plaster mill:

Calciner	1.65
Operator	1.48-1/2
Packers	1.43
Truckers	1.32-1/2

Wallboard plant:

Working foreman	1.70
Quality man	1.52-1/2
Supply man	1.37-1/2
Boiler operator	1.55
Bunker men	1.45
Machine operator	1.50
Car bracer	1.40
Electric truck driver	1.40

Knife operator	$1.40
Inspector	1.40
R. H. puddle and edge man	1.42-1/2
Paper hanger	1.45
Puddler	1.37-1/2
Loader	1.35
Take-off	1.35
Laborer	1.32-1/2

Maintenance:

Chief electrician	1.90
Electrician	1.75
Carpenter	1.75
Stockroom parts man	1.55
Helpers	1.45
Machinist	1.85
Mechanics	1.55 to 1.75
Buhr dresser	1.70
Mechanic on tramway	1.75
Oiler	1.50
Helper	1.45

Working foreman receive 10¢ per hour over the highest established rate of the men they supervise.

Time and one half is paid for work in excess of 8 hours daily and 40 hours weekly.